Discrimination Study with the Man-Portable Vector EMI Sensor at Former Camp Beale, California

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14. ABSTRACT

The MPV is a handheld Electromagnetic Induction (EMI) sensor developed for the purpose of extending UXO discrimination to most land locations, especially at sites inaccessible to wheel-based platforms. Key features of the MPV include an array of five vector receivers, a widely programmable user interface that allows different survey modes, and a portable positioning system based on a primary field monitor ? the MPV transmitter acting as a beacon. The initial MPV prototype was developed by USACE-CRREL with SERDP (MR-1443) before integrating ESTCP demonstration program (MR-201005) with Sky Research, G&G Sciences and CRREL. The prototype was ruggedized and field-tested at the Standardized UXO Test Site at Yuma Proving Ground, AZ in October 2010. The demonstration was successful, obtaining over 90% detection and discrimination rates on the blind grid for targets within one meter depth. In Spring 2011 ESTCP organized a field demonstration study for man-portable discrimination systems at former Camp Beale, California. The site included sloping terrain, large boulders, open field and forest. Our team deployed the MPV technology to collect cued interrogation data over more than 900 anomalies over 2.5 weeks in June. Because UXO discrimination with MPV data requires collection of multiple soundings to characterize an anomaly, accurate positioning is crucial. The MPV-specific beacon positioning system was used throughout the site and proved to be essential under thick tree cover, where positional accuracy with GPS was severely degraded. Data collected in the field, on the Instrument Verification Strip (IVS) and test pit were made available for advanced geophysical processing. Several research groups were involved in independent analysis. Data were inverted and classified to build prioritized dig lists. This presentation presents the field data collection effort and results from the data analysis and classification.

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DISCRIMINATION STUDY WITH THE MAN-PORTABLE VECTOR (MPV) EMI SENSOR AT FORMER CAMP BEALE, CALIFORNIA

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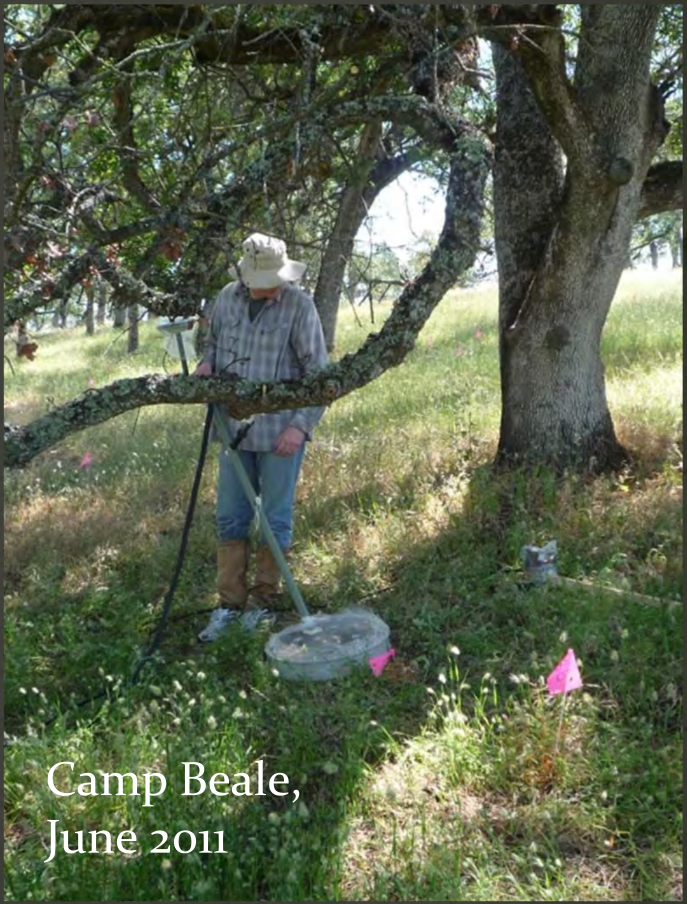
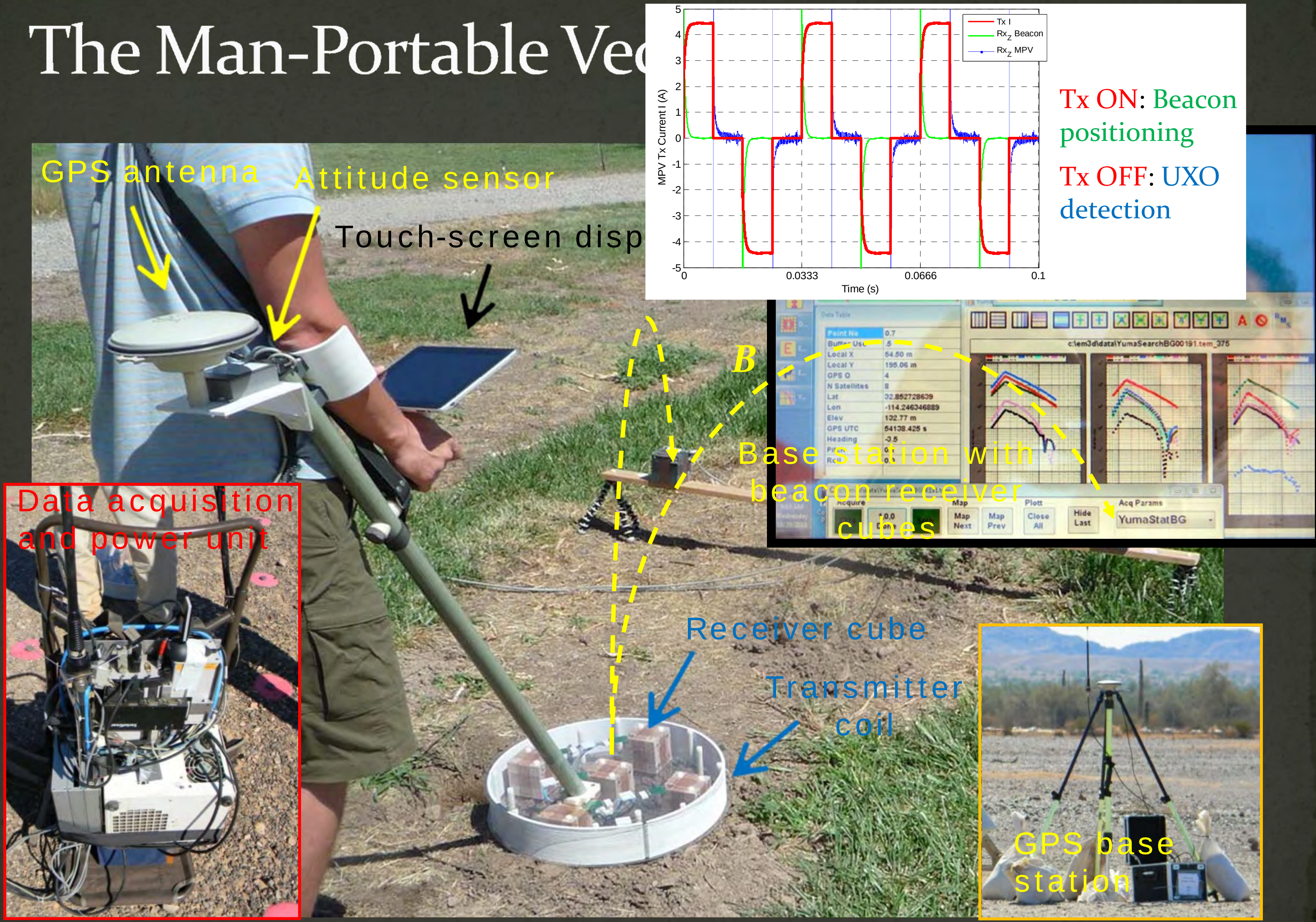
Outline

- Introduction
  - The MPV sensor
- Data collection
  - Cued interrogation with MPV
  - Training and sensor verification
- Data analysis
  - Effect of background signal
  - Geophysical inversion
  - Classification
- Conclusion



Camp Beale,
June 2011

The Man-Portable Vec



Cued interrogation survey with the MPV

Objective: Acquire high quality data to discriminate between munitions and clutter

Factors affecting discrimination:

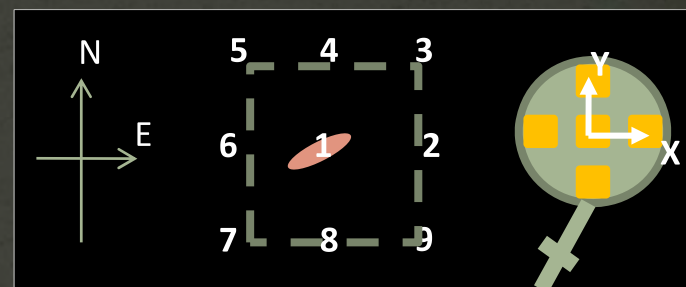
- Signal to Noise Ratio (SNR)
- Spatial coverage for target localization
- Late-time decay for target shape and material
- Accurate positioning
- Characterization of noise sources

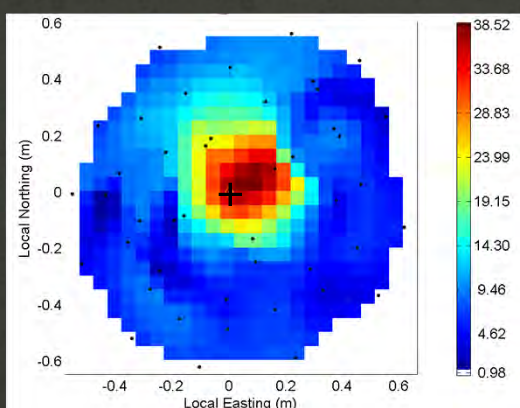
Cued interrogation survey with the MPV

Factors affecting target characterization:

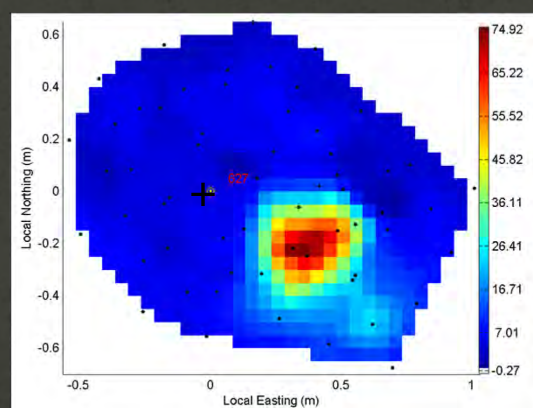
- SNR: Static soundings and stacking
- Target location/Coverage: Multiple soundings

Standard Operating Procedure (SOP):
3 x 3 grid centered on flag
1 tilted measurement





Gridded image for vertical component data



Extended survey pattern for target offset

Tilted measurement for near-field transverse excitation

Cued interrogation survey with the MPV

Factors affecting target characterization:

- Long transients for discrimination: 25 ms excitation and decay

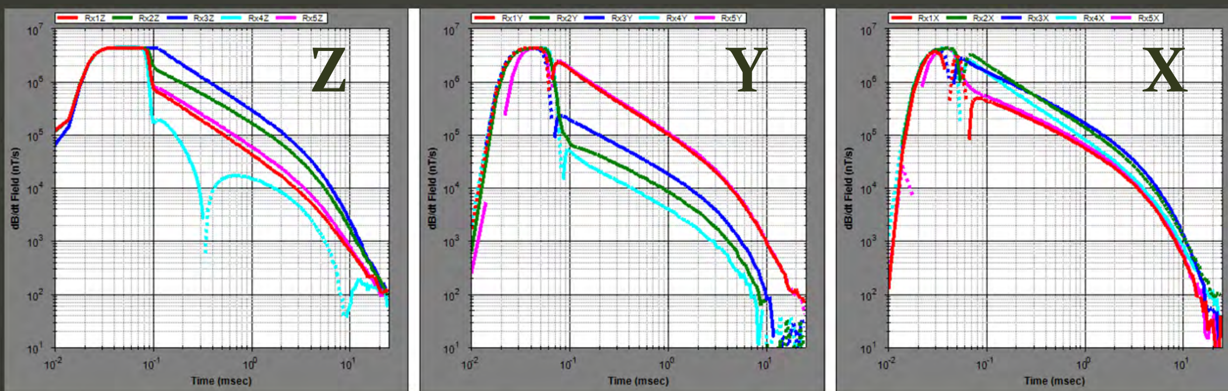
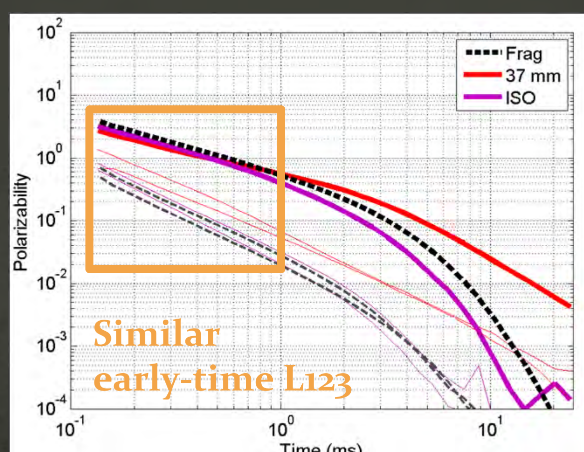
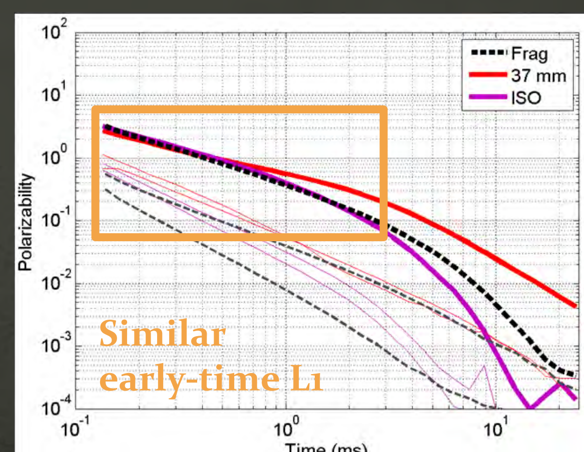


Fig.: MPV data collected on top of 60 mm mortar

Fig.: Early-time polarizabilities for frag, 37 mm and ISO are similar. Discrimination requires late time information (>3 ms)

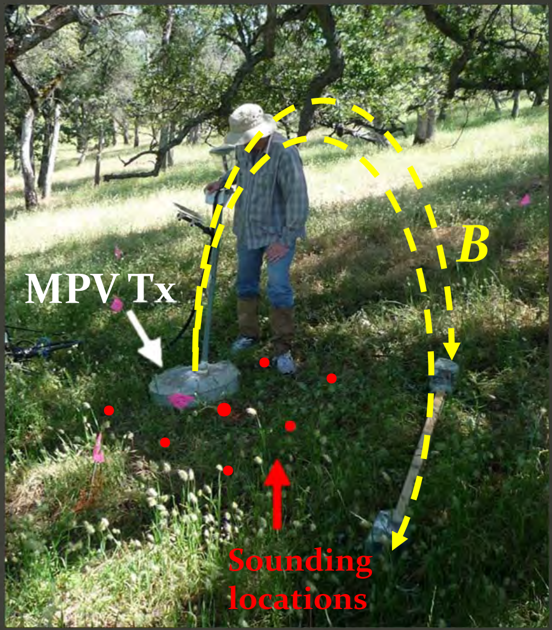




Cued interrogation survey with the MPV

Factors affecting target characterization:

- Accurate positioning with beacon:
  - Beacon system is applicable everywhere
  - GPS can predict sensor head location within 1-2 cm in open field and can be used to control beacon accuracy



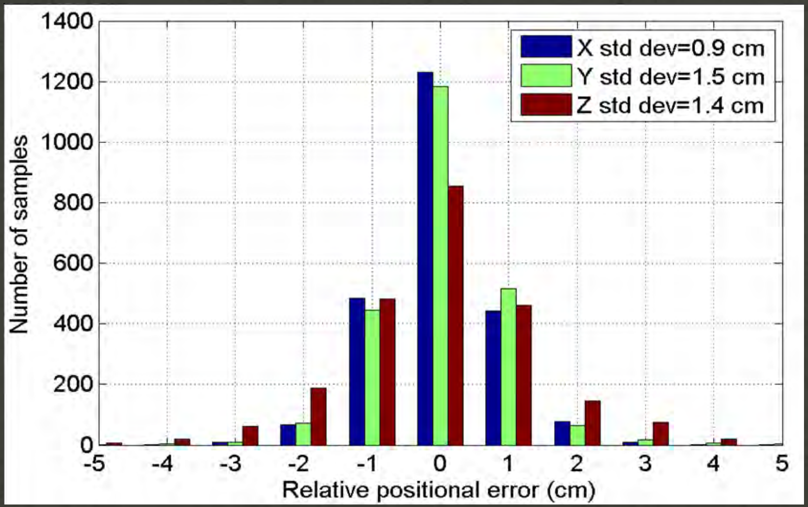


Fig.: Relative position of GPS and beacon system in open field area at Camp Beale

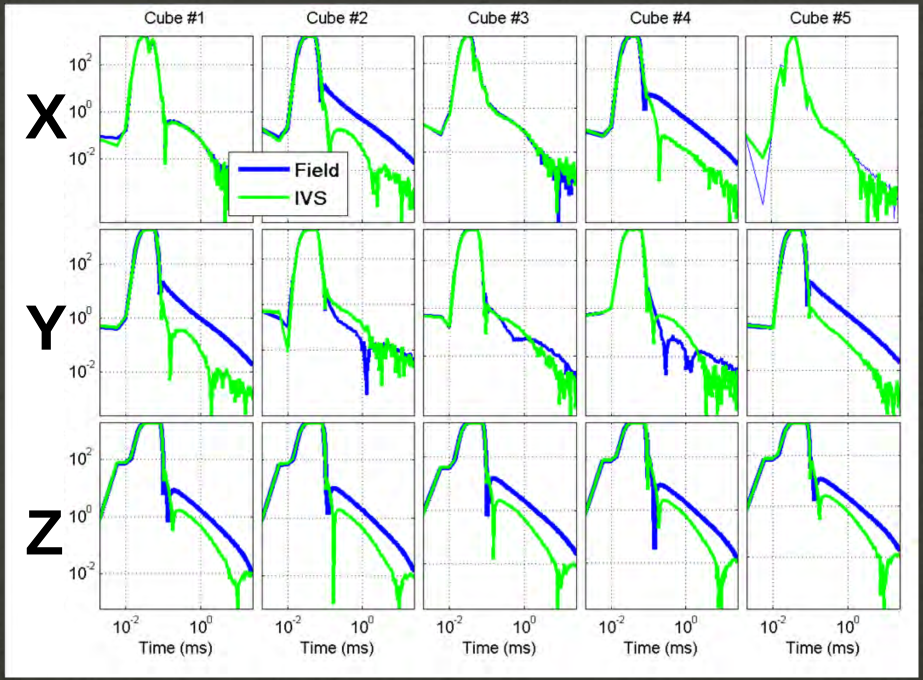
⇒ Beacon positioning is accurate to 1-2 cm

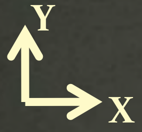
Cued interrogation survey with the MPV

Factors affecting target characterization:

- Background noise characterization:
  - Acquire frequent background soundings
  - Take in-air measurements

Fig.: Background response in field and at IVS





Red soil: iron oxides

⇒ Magnetic soil affects 9 of 15 receivers on MPV

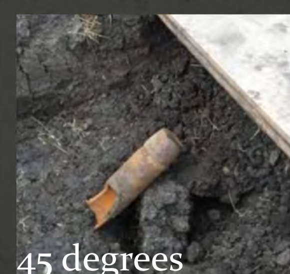
Training, calibration and verification


Training pit


Horizontal

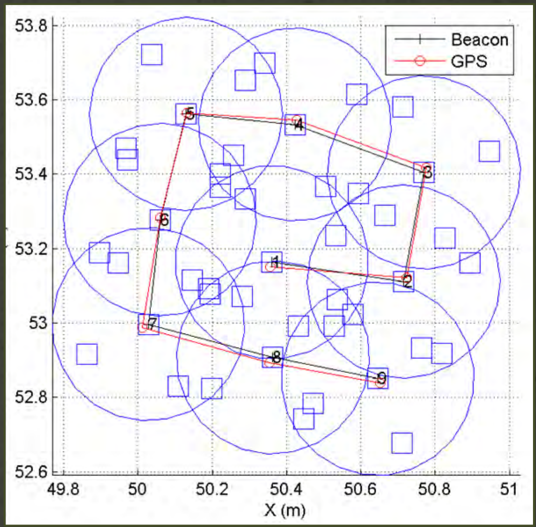

Vertical

Training targets:
105 mm, 81 mm,
60 mm, 37 mm,
ISO and frag


45 degrees

Training, calibration and verification

- Instrument Verification Strip (IVS)
  - Verify MPV response over 5 buried targets:
    105 mm HEAT, 60 mm, 37 mm, shotput and ISO (4"x 1.25" steel cylinder)
  - Verify sensor noise:
    IVS located in terrain with low geologic EM response
  - Verify beacon positioning accuracy relative to RTK GPS:
    IVS located in open field
  - Daily survey



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Data analysis: Effect of magnetic soil

- Local magnetic soil affects MPV EMI data in predictable manner
  - Log-linear time decay
  - Response mirrors sensor (if homogeneous soil and smooth surface)
  - For MPV: vertical and radial components are affected
  - 6/15 components are soil insensitive
- Survey trade-off:
  - Raise sensor to diminish soil response
  - Or, stay close to ground to maximize target response
- Assumption:
  - Data processing can mitigate soil effect
  - Survey close to ground for max target response

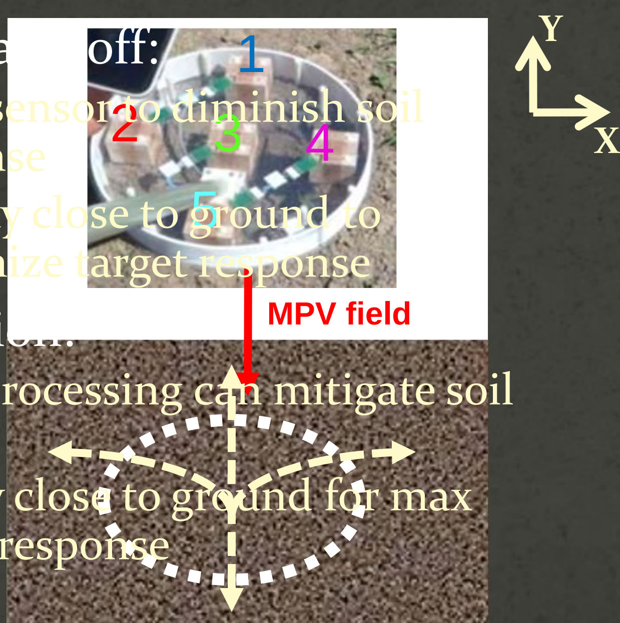


Fig.: Soil response mirrors sensor

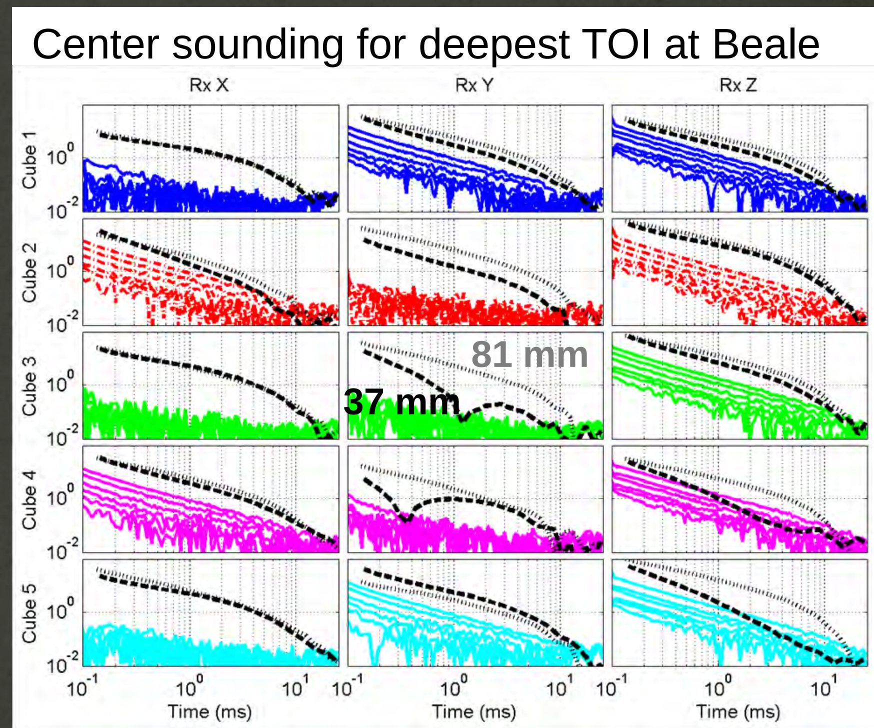


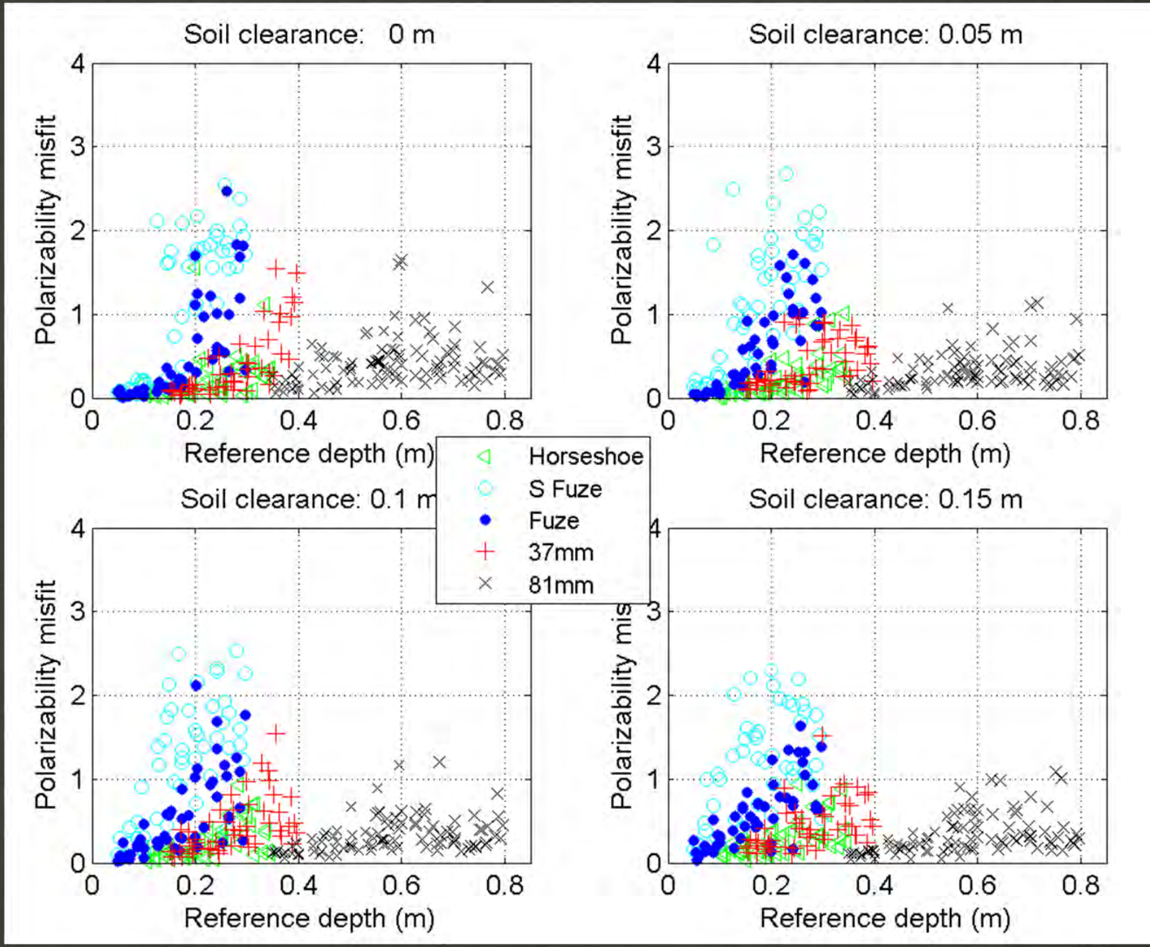
Fig.: Sensor clearance test. Soil response at different heights (0, 4, 11, 15, 22 and 33 cm)

Data analysis: Effect of magnetic soil

- Effect of soil clearance on discrimination

Monte Carlo simulations:
- Get soil versus height relationship
- Identify 200 soil soundings to sample from
- Predict soil response at different heights
- Predict target response at different depths
- Apply soil correction
- Invert data

Result:
Better parameter recovery when sensor is kept close to ground



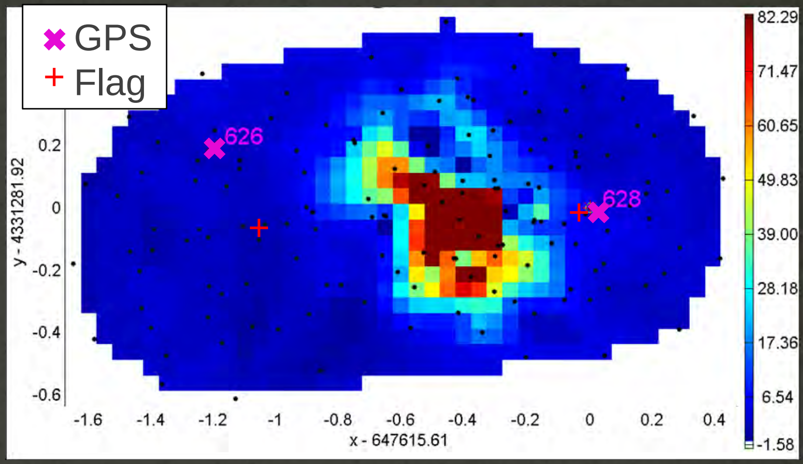
Data analysis: Pre-inversion QC

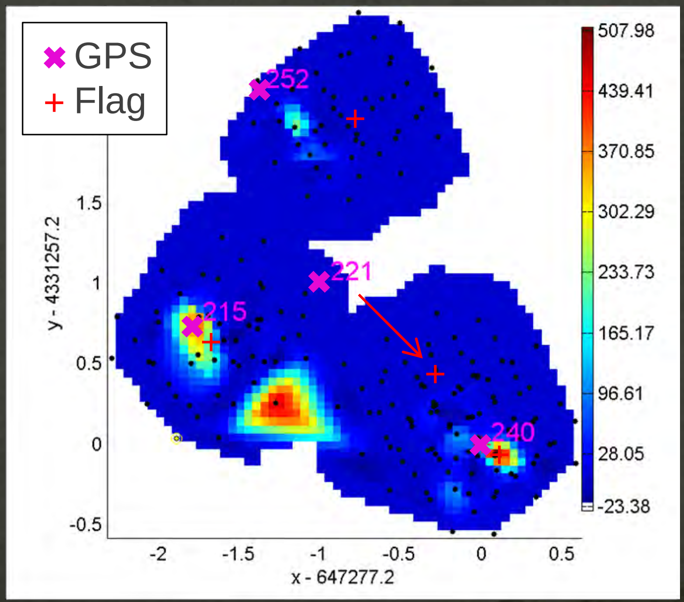
Situation

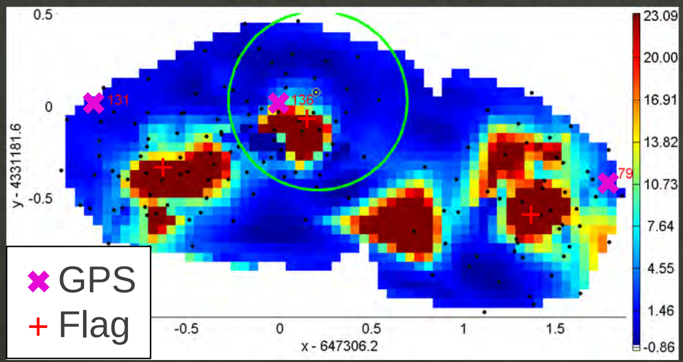
- Multiple instances of close targets
- Ambiguity on anomaly location relative to flag (trees, slope)
- Necessity to aggregate data for multiple flags and use masks

Masking procedure

- Isolated anomalies
  - No intervention
- Case of close targets
  - Associate anomaly to correct flag
  - Mask







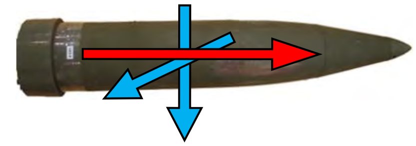
Data analysis: Geophysical inversion

<u>Guiding principle</u>: Try multiple approaches to defeat potential nuisance from soil background

- Standard approach
  - Single target inversion: sufficient most of the time
  - Multi-target inversion: 2 targets in field of view, or 1 target + soil
  - Test different noise estimates
- Site specific approach for presence of magnetic soil
  - Single target: invert only soil-insensitive components of data
  - Multi-target: invert all data, using single-target solution + a secondary model to fit residual

Dipole model

L_1: Axial Polarizability



L_2, L_3: Transverse Polarizabilities

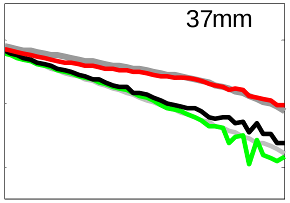
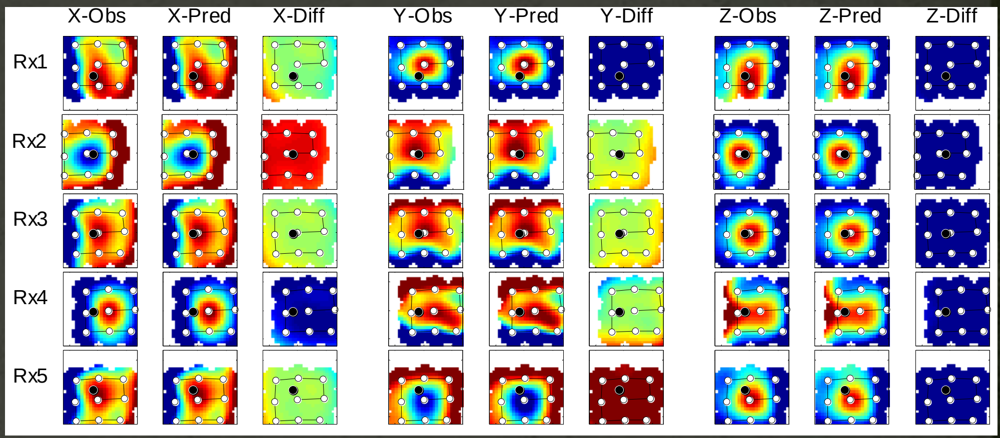


Fig.: Recovered polarizabilities

Data analysis: Inversion QC

Guiding principle:
- Minimal intervention: automated QC
- Keep all plausible models and let classification select likely TOI



Procedure:
- Verify data fit
  - 100% successful dipole fit for isolated anomalies
- Case of close targets
  - Verify fit to individual anomalies
  - Re-mask if needed and re-invert until all anomalies are fit
- Pass/Fail inversion
  - Only fail results with poor fit
  - Let classification identify TOI

Data analysis: Classification

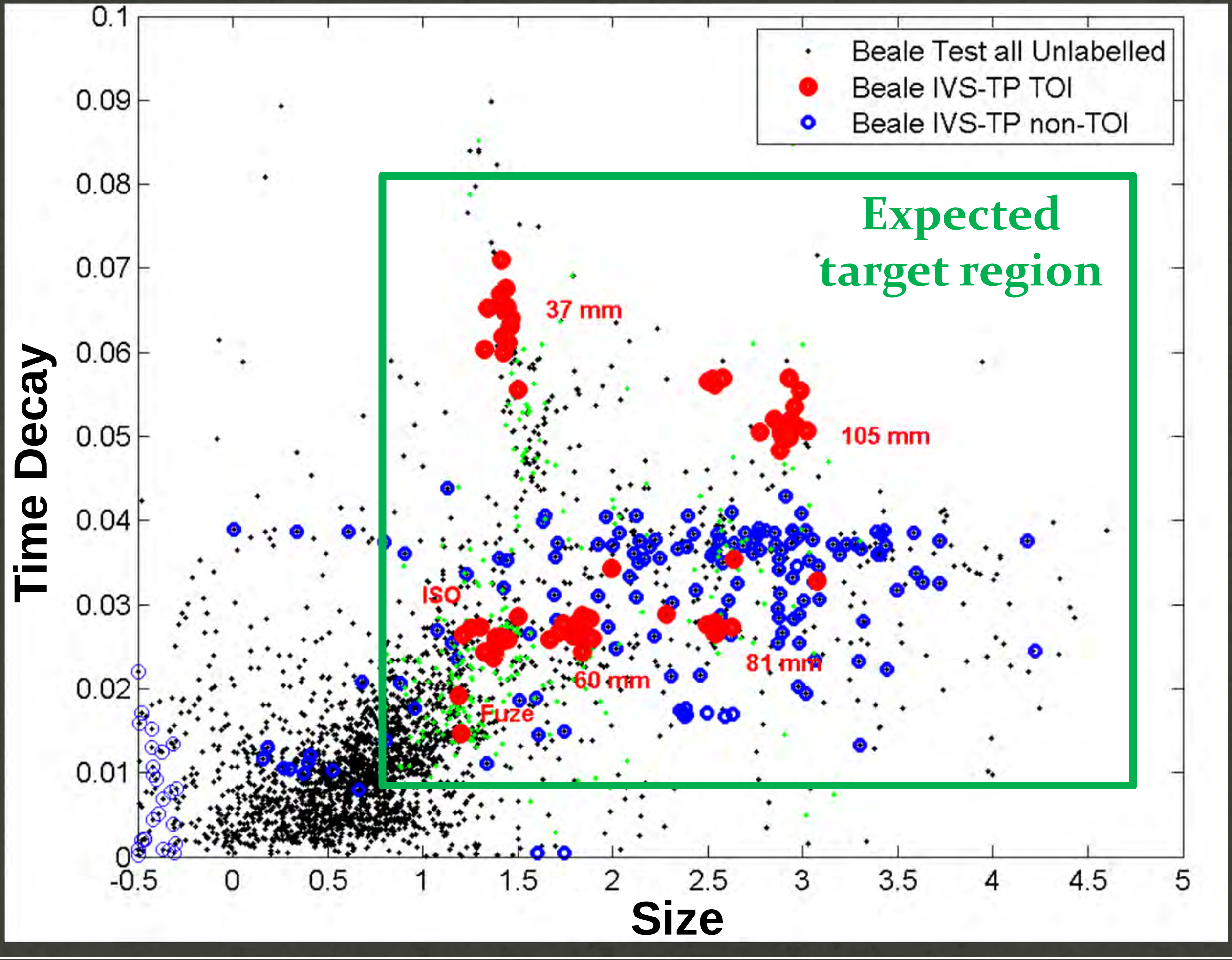
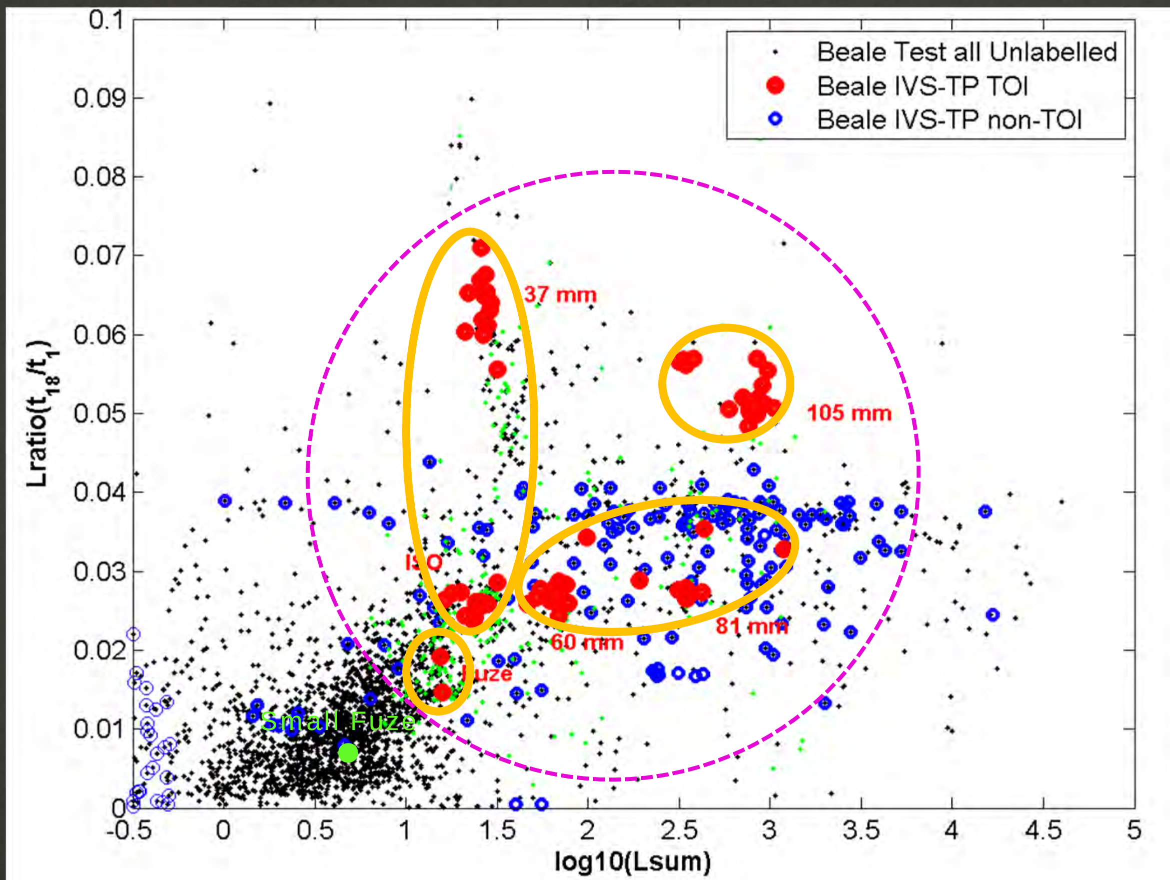
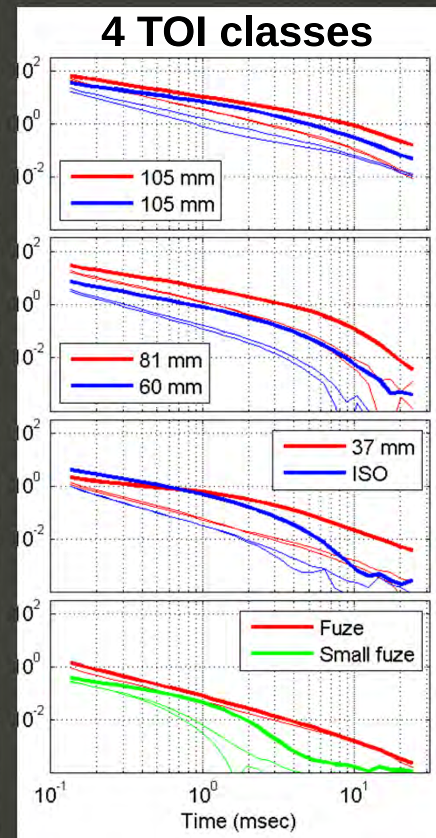


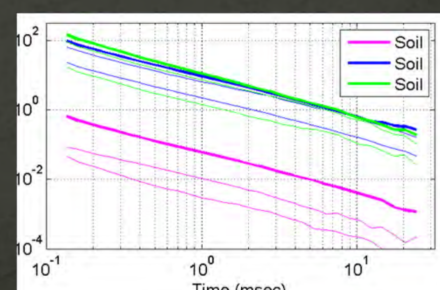
Fig.: Simplified classification feature space: Size vs. Time Decay

Data analysis: Classification

Features: Polarizability transients (L1, L2 and L3)
Statistical classifier: Support Vector Machine (SVM)
Classes: 4 UXO classes against clutter and soil
Application: Cascade from large to small TOI







Data analysis: Classification

L1, L2 and L3)
Machine (SVM)
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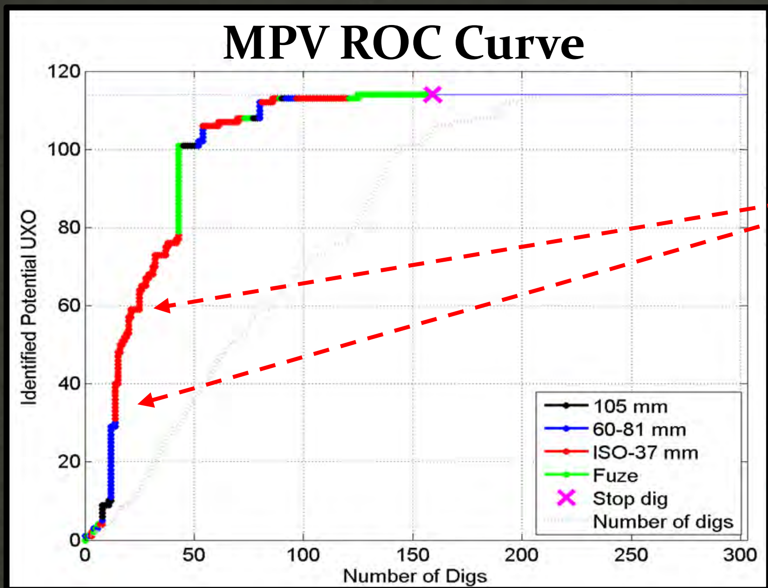
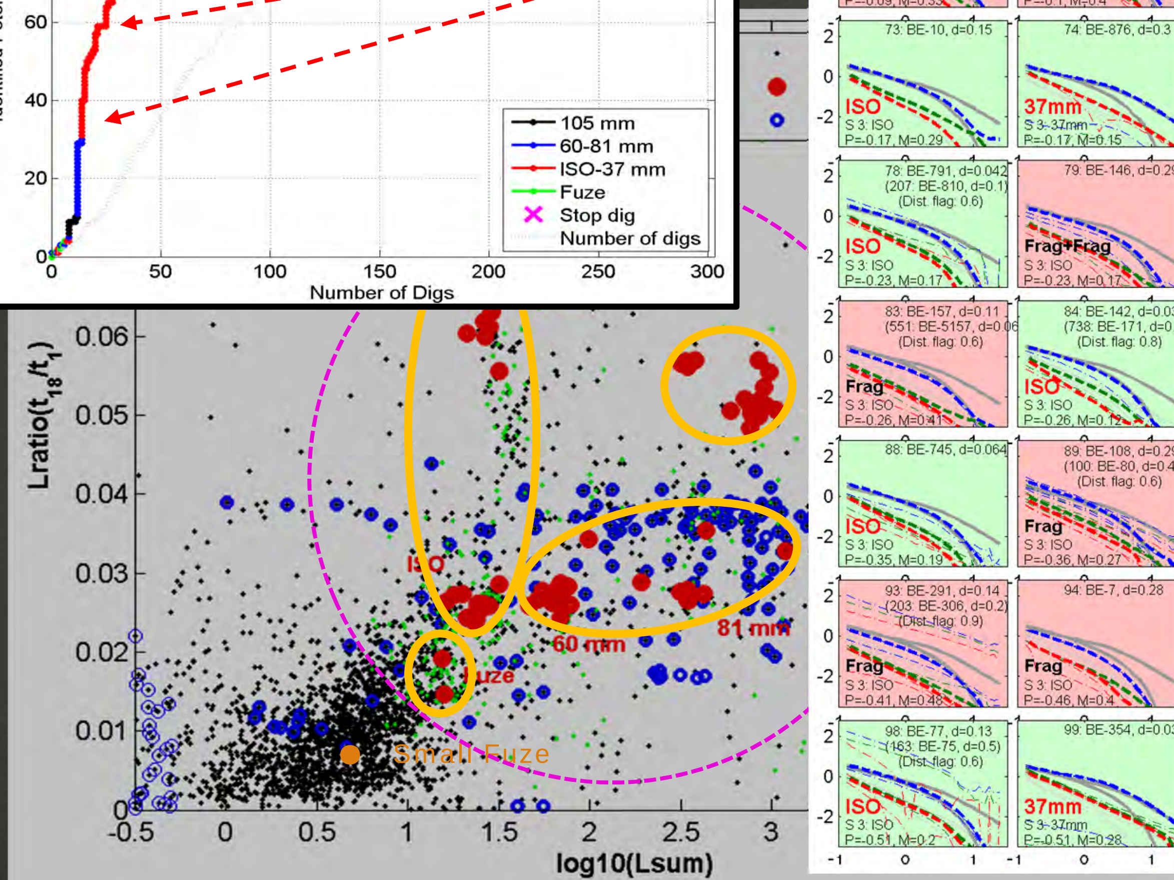
sma

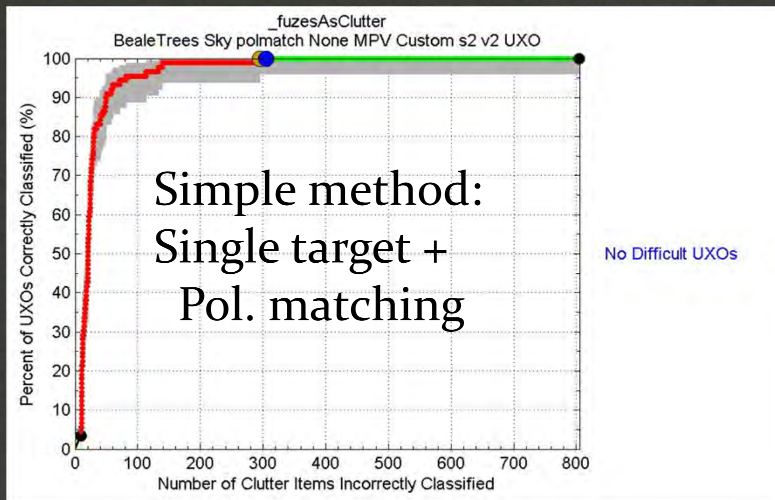
Dig order according to

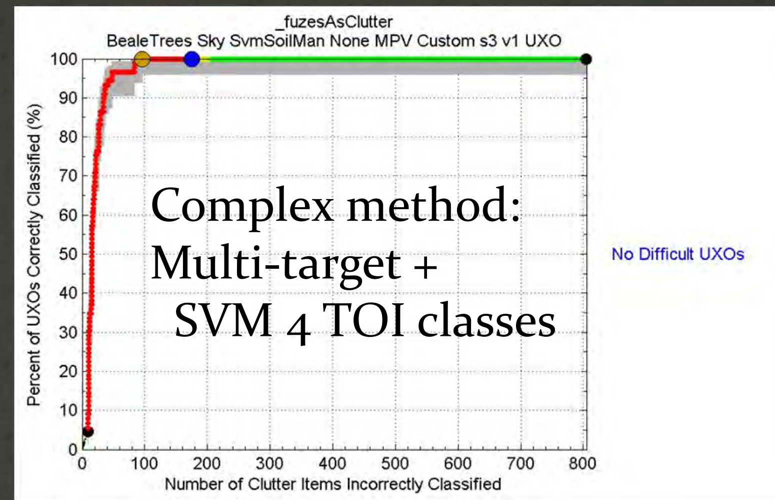


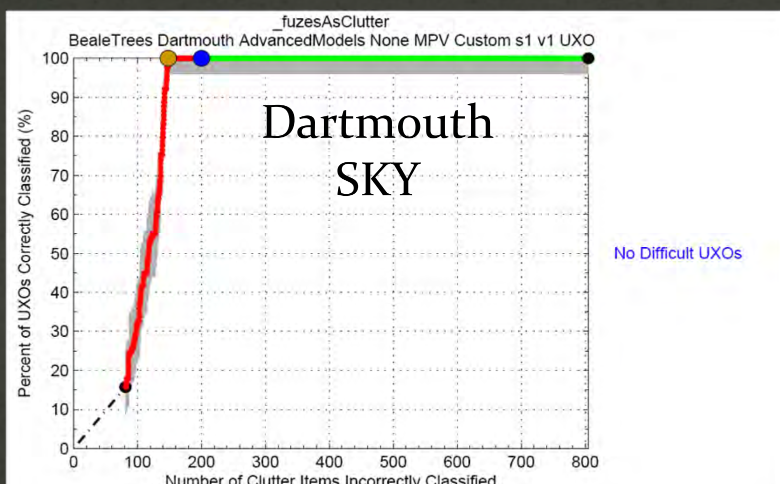


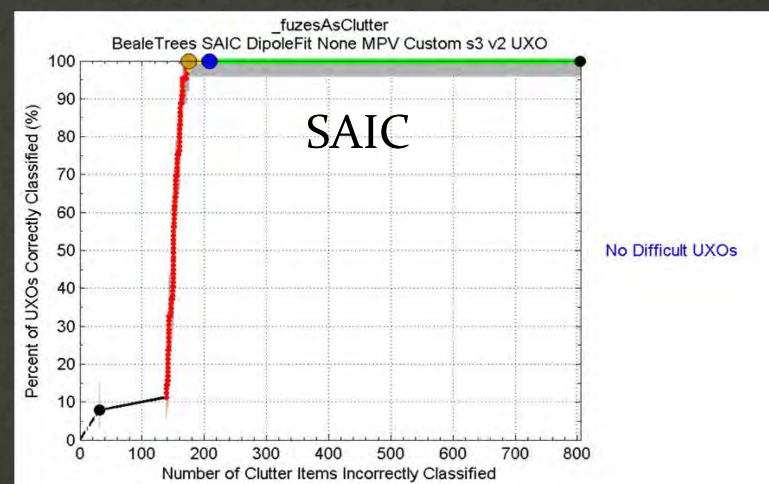
Data analysis: ROC curves

Fuze as clutter



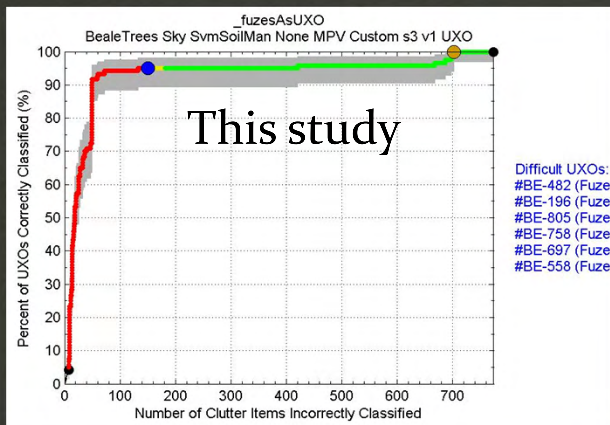


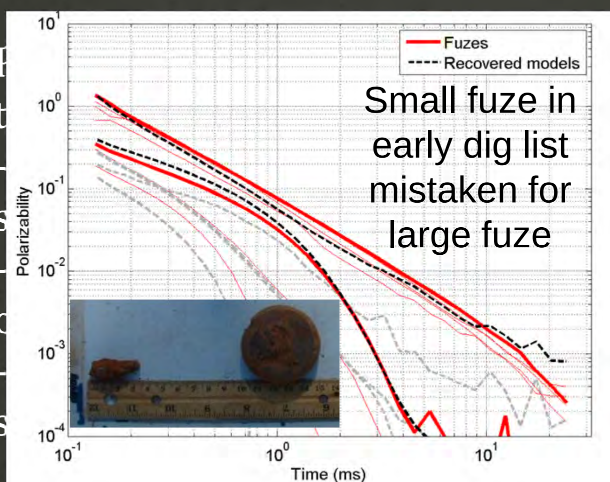


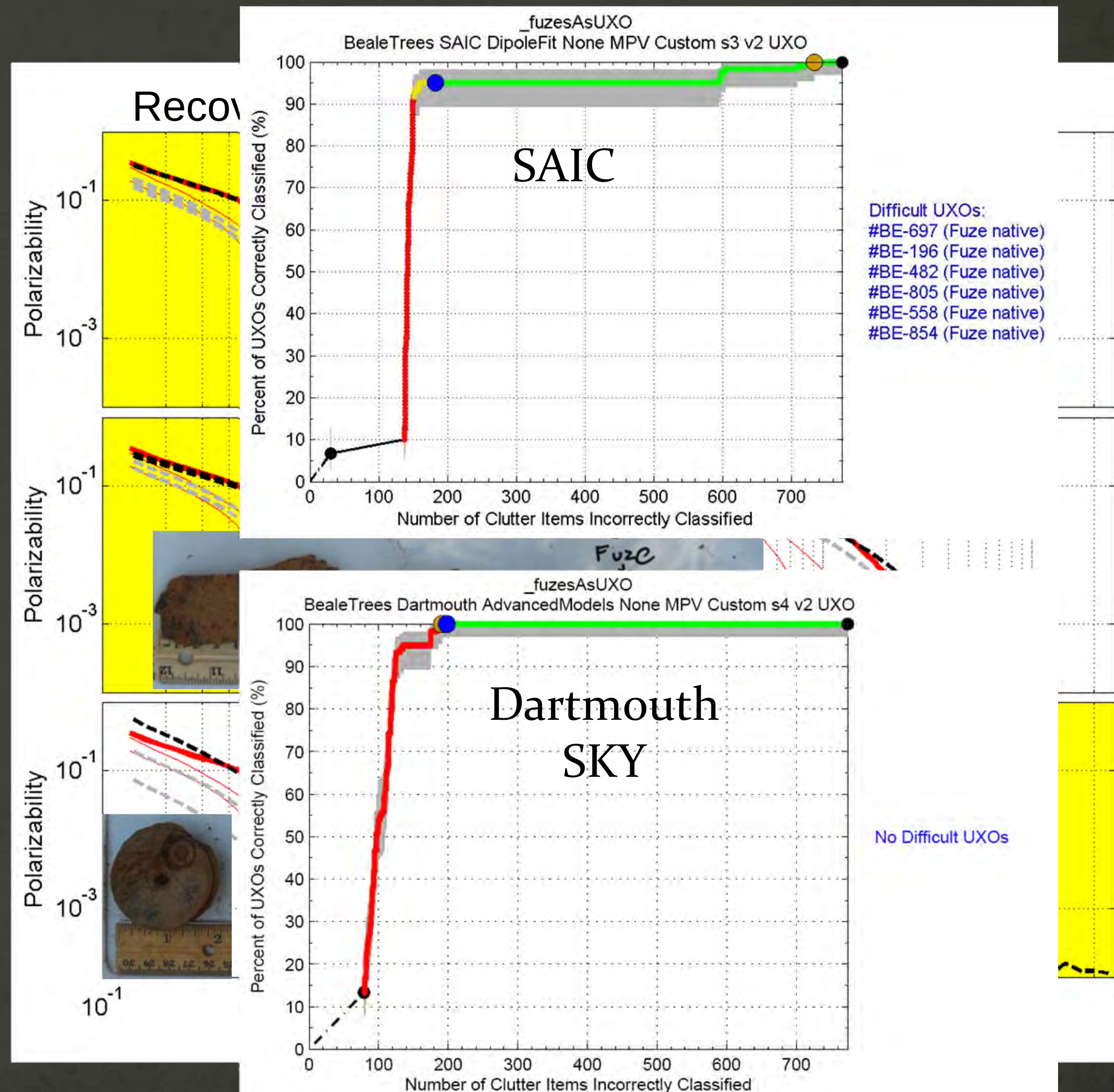


⇒ Every analyst group was successful at finding all TOI with minimal false alarm rate using MPV data

Data analysis: Small fuzes







Conclusion

- Successful demonstration
- High quality data
  - All TOI were detected and invertible
  - Low false alarm rate
- Beacon positioning is accurate
  - Applied on entire site
  - Discrimination was successful
- MPV sensor is efficient and reliable
  - Productivity of 90 targets/day
  - Limited downtime

⇒ MPV offers strong discrimination capabilities for difficult survey sites with a highly maneuverable, handheld form factor

- Future work
  - 2-3 field demonstrations next year
  - Planning to improve QC procedures for increased productivity

Acknowledgement

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